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MOTIONS IN BARRED SPIRALS. VI. THE ROTATION AND VELOCITY FIELD OF NGC 613

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ABSTRACT

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From spectra taken at McDonald and Lick Observatories, velocities in the nucleus and in the outer emission knots of the barred spiral NGC 613 were measured. The recession velocity of the galaxy is +1493 km/sec. From the steep velocity gradient across the nucleus a mass of $9 \times 10^9 M_\odot$ for the nuclear region is determined. The northwest emission knots, 80" from the center, have velocities of the order of 150 km/sec with respect to the nucleus. The southeast emission knots have velocities which range from almost 0 (60" from the center) to 250 km/sec (100" from the center), with respect to the nucleus. To account for this strange velocity variation, various models are considered. It is suggested that NGC 613, like NGC 1097 and NGC 6951, is a type of "fat bar" spiral, with a small nucleus and a large velocity of circulation in the nucleus, low rotation of the bar as a whole, and outer features reminiscent of spiral arms in ordinary spirals. For such a galaxy, the estimate of the total mass is highly uncertain.

Aethar

I. INTRODUCTION

Fig. 1

NGC 613 has been classified SBc by Hubble. A plate is shown in Figure 1. Although the orientation of a galaxy is such that much of the bar is obscured by prominent dust lanes, the bright central region and the emission knots at large distances from the nucleus make it possible to study the velocity field of the galaxy in some detail. The chief observational limitation is the southerly declination of the object. The nuclear region consists of bright HII regions forming spiral arms around a central nucleus about 12" across; bright emission knots outline a continuation of the arms in the outer regions of the galaxy, to a distance of about 100" from the nucleus. Unlike the typical SBc galaxy which has only two arms making an S-shape, NGC 613 has several well-defined arms, and a suggestion of crossing arms in the outer regions. In its overall appearance, NGC 613 closely resembles NGC 1097 and NGC 6951, both of which may be more face-on examples of the "fat bar" type of barred spiral, i.e., the type with a bar that is thick in the plane of the galaxy, but not thick in the direction perpendicular to the plane. Both NGC 1097 and NGC 6951 may be seen in the Hubble Atlas (Sandage 1961).

Seconds of arc,

and face

II. OBSERVATIONS

A number of spectra of NGC 613 were obtained in November and December, 1960, with the B spectrograph at the prime focus of the 82-inch McDonald telescope, with the slit in different orientations. The exposures and position angles are listed in Table 1. An additional spectrum in position angle 105°.5 was obtained in October, 1963, with the prime-focus spectrograph of the 120-inch telescope at the Lick Observatory. For this, we used a combination of the thick Schmidt camera and grating giving a dispersion of

Table 1

195A/mm at Hα and a scale of 84" per mm perpendicular to the dispersion. A reproduction of this spectrum is shown in Figure 2. The emission lines of Hα, [N II], and [S II] are prominent.

A sketch of the galaxy is shown in Figure 3; the orientations of the slit are indicated. For each position angle, the limits of the regions for which velocities could be measured are indicated by the short bars. From the appearance of the galaxy, the line of nodes was estimated to be in position angle 115°; however, estimation of the line of nodes from the shape of the galaxy is uncertain for a barred spiral, as one tends to be influenced by the presence of the bar. In position angle 115° the bright knots in the arms extend to about 100" from the center. Velocities of the most distant bright knots in the southeast arm were obtained with the slit in position angle 121°. Observations of other knots in this arm were made with the slit in position angle 114° through the knots, but not through the nucleus. At 90° to the estimated line of nodes, in position angle 25°, observations of only the bright central nucleus were obtained.

All spectra were measured with the Mann two-coordinate measuring instrument at the University of California, San Diego, with the perpendicular cross wires set at 45° to the direction of travel of the screws. The curvature corrections previously obtained were applied. On five of the spectra (B 681, 683, 684, 688, 690), night-sky lines could be measured as a check on systematic errors; in all cases there was no systematic run of errors with position along the length of the slit. Wavelength measures were made at intervals of 20 μ perpendicular to the dispersion. For the McDonald plates, this corresponds to a distance of 2".9; the greater scale of the Lick instrument gives 20 μ = 1".7. With the smaller dispersion and longer slit of the McDonald spectra, only Hα and [N II] λ6583 are measurable, to a distance of 87" from the nucleus on the north-west side. The greater dispersion of the Lick spectrum L 620 makes it possible to measure Hα, [N II] λ6548, λ6583, and [S II] λ6717, but a shorter slit was used, and the measures extend only over about 15". The McDonald spectrum B 688 and the Lick spectrum L 620, both in position angle 105°.5, give measures that are in very good agreement, as will be seen below, and the Lick spectrum, with its greater scale and dispersion, thus provides a valuable check on the spectra obtained earlier at McDonald. In addition, in a galaxy such as this, with a steep velocity gradient across the nucleus, the increase in scale provides additional velocity measures where the steep slope makes them particularly desirable.

The measured velocities, reduced to the sun and corrected for the basic solar motion, are given in Table 2. This procedure is a departure from our previous publications, in which measured velocities were reduced to the sun, but no additional reduction was included. We have decided to reduce the observations to the local standard of rest, first so that our velocities can be more readily compared with those obtained from 21-cm radio observations of external galaxies; and second, because fairly well-established values of the reduction terms are available. For the motion of the sun with respect to the local standard of rest, we adopt the basic solar motion determined by Vyssotsky and Janssen (1951); V_o = 15.5 km/sec toward $\alpha = 265°.0$, $\delta = +20°.7$, corresponding to galactic velocity components $\dot{x} = +10.2$, $\dot{y} = +10.1$, and $\dot{z} = +5.9$ km/sec, with positive $\dot{x}$ directed toward the galactic center. NGC 613 has 1950 coordinates $\alpha = 1^h32^m.0$, $\delta = 29°40'$, corresponding to $\ell^{II} = 228°$, $b^{II} = -80°$. At this position, the correction for the basic solar motion is $\Delta V_r = -8.6$ km/sec.

From the velocities listed in Table 2, the mean velocity of the galaxy as a whole has been taken to be +1525 km/sec, from the adopted mid-point of the nucleus. Humason, Mayall, and Sandage (1956) give +1558 km/sec for the uncorrected velocity of NGC 613, in good agreement with the present adopted value. Following the recent I.A.U. (1963) recommendation, we take $\dot{y}$ = 250 km/sec as the velocity of rotation of our Galaxy at the position of the sun. For NGC 613, the correction for galactic rotation is ΔV_g = -32.3 km/sec. The corrected recession velocity of NGC 613 is then +1493 km/sec.

As can be seen in the Lick spectrogram shown in Figure 2, the intensity distribution of the continuum perpendicular to the dispersion is not symmetrical with respect to the extent of the emission lines, since the continuum has a greater extent in the northwest direction than in the southeast direction. In addition, the brightest part of the continuum is not located in the geometrical center of the continuum. It is assumed that the distribution of early-type stars, ionized gas, and obscuring dust has the symmetry of a barred spiral, namely, rotation through 180° about the axis of the galaxy is a covering operation, and that there is no plane of symmetry containing the axis of rotation. The dust lanes which can be plainly seen in Figure 1 and which are typical of those seen in barred spirals, have this type of symmetry. The southeast part of NGC 613 is approaching the observer; the dust lanes at the southeast edge of the nucleus are then in the foreground and obscure the continuum radiation from this region. The effect of this obscuration is sufficiently pronounced so that spectrum B681, a 30^m exposure in position angle 115°, has measurable lines on one side of the nucleus only. Because of this asymmetry, there is some uncertainty in locating the mid-point of the nucleus. The adopted value, however, is confirmed in general by all eight spectra.

With the adopted value of +1525 km/sec for the center of the galaxy, the velocities relative to the center have been found from the values listed in Table 2; those in position angle 105°.5 are plotted in Figure 4 and those in position angles 115° and 121° are plotted in Figure 5. For the spectrum B709, in position angle 114° and not through the nucleus, the values have been reduced to position angle 115° through the nucleus, by means of the usual projection formulae, assuming that the velocities are purely circular ones (cf. Burbidge, Burbidge, and Prendergast, 1960a). For these knots, the position angles with respect to the nucleus range from 132° to 125°; i.e., they lie close to the adopted line of nodes. The projection factors are therefore small; the maximum difference comes out to be 5 km/sec in the velocities, and 3 seconds of arc in the distance. The values plotted in Figure 5 are thus very close to the observed line-of-sight velocities.

III. THE VELOCITY FIELD

As has been pointed out in earlier papers in this series, the analysis of the velocity field of barred spirals is more difficult than for ordinary spirals. In ordinary spirals, both a plane and an axis of symmetry can be assumed. Then the further assumption of purely circular orbits and the geometry of the orientation of the galaxy are sufficient to define completely the velocity field of the galaxy. For a barred spiral, since there is no axisymmetry, the velocity field cannot be uniquely specified from observed line-of-sight motions only.

Danver (1942) gave 124°.4 as the position angle of the line of nodes, and 46°.9 for the angle between the normal to the plane of the galaxy and the line of sight. This choice of the line of nodes may have been influenced by the bright emission knots southeast of the nucleus at position angle 128°; however, it is not very different from our adopted value of 115°. We have used his value of 47° for the inclination in the following calculations.

The velocity curve in the central region of NGC 613 is well defined. From the measures in position angle 105°.5 (shown in Figure 4), the velocity curve is approximately symmetrical from -20" to +20", with $|V_{max}| \approx 300$ km/sec. From the Lick spectrogram, which has greater weight, the variation appears strictly linear between -7.5" and +7.5", with a velocity range of 200 km/sec with respect to the central velocity. From the adopted recession velocity, V = 1493 km/sec, and a Hubble constant of 75 km/sec per Mpc, we obtain a distance of 20×10^6 pc for NGC 613; at this distance, 1" = 96 pc. Thus the angular velocity is constant over a nuclear region with diameter $\sim$ 1400 pc. A similar result is obtained from the observations in position angles 115° to 121°.

In the outer regions of the galaxy, a decided asymmetry is observed. On the northwest side of the galaxy there are no measures of velocity between about 20" and 70". From 70" to 90" velocities of the order of 200 km/sec with respect to the nucleus are measured. On the southeast (approaching) side, the observations are very different. If the observed velocities are interpreted as circular velocities, the bright knots at y = 60" have only a very small rotational velocity with respect to the center; the rotational velocity increases with increasing distance from the center, reaching a maximum (negative) projected velocity of about -240 km/sec at y = 100". The overall appearance of the velocity curve is strikingly similar to that observed for the barred spiral NGC 5383 (paper V in this series; Burbidge, Burbidge, and Prendergast, 1962). For this galaxy also, one end of the velocity curve has a steep gradient, in the opposite sense to that expected for Keplerian orbits. Although it was clearly pointed out in the discussion of NGC 5383 that no unambiguous model can be presented for such non-axisymmetric velocity fields, it is possible to examine several alternatives for the present case.

The main problem that must be solved if we are to understand the velocity field in NGC 613 is the following. The southeast emission knots at y = 60" have almost no line-of-sight velocity with respect to the nucleus. If only circular velocities were present, these points would be at rest with respect to the nucleus, a physically unlikely situation. We have looked at various models of the velocity field of NGC 613, and conclude that there are a number of possibilities which we summarize below.

(1) If the true line of nodes lies far from the adopted position angle of 115°, then the computed projection factors for the velocities in the southeast knots are not correct. However, calculations show that a shift of the line of nodes by as much as 35° will increase the velocity in the plane of the galaxy at y = 60" only from -19 km/sec to -36 km/sec, if the velocities are purely circular. If the true line of nodes were almost 90° different from the adopted position angle, the velocities at y = 60" could be increased by any desired factor, but the velocities further out in the same arm would then become impossibly large.

(2) Conversely, if the line of nodes is in position angle 115° but only radial motions are present, impossibly large radial motions at y = 100" result from the measured values. Combining circular and radial motions clearly does not help. Both (1) and (2) result from the fact that, if zero line-of-sight velocity is observed with respect to the center, and we have no a priori knowledge of the nature of the velocity field, we can say only that the true velocity has undetermined magnitude and is perpendicular to the line of sight.

(3) If the galaxy is restricted to a plane, but z-motions and circular velocities are present, the z-component must be ~ 300 km/sec, with assumed circular components ~ 100 - 200 km/sec, to produce the observed results.

(4) If the outer southeast arm projects out of the principal plane of the galaxy, there is still great difficulty in interpreting the observations in terms of circular motions and motions along the arm. Any motion along the arm would contribute most to line-of-sight observations at large y because there the measured velocities along the arm would have the largest component in the direction toward the observer. However, the measures demand that the greatest contribution from z-motions comes at around y = 60". It is possible, of course, to construct a model of positions and velocities in the outer arm which would exactly reproduce the observations. However, such a model would have little value in increasing our understanding of the dynamics of barred spirals.

A theoretical model has been proposed by one of us and numerical computations have been carried out with the IBM 7094 at NASA, on the flow of gas in the gravitational field of a prolate spheroid rotating end over end with given angular velocity (Prendergast 1964, 1984). These computations show that matter may be expected to escape from the ends of the bar and form trailing spiral arms. Within the bar a complicated flow pattern appears, with matter circulating around the nucleus in the same direction as the rotation of the system as a whole.

Consider a barred spiral with a very thin bar: that is, one with dimensions along the bar much greater than at right angles to it, measured in the plane of the galaxy. An example of this kind of galaxy is NGC 1300 (Sandage 1961). In this case, we say that the gravitational force at any point on the long axis of the bar is very nearly balanced by the rotation of the bar, and that there may be a small pressure gradient as well, presumably giving rise to an effective force directed away from the nucleus. For the support at right angles to the long axis of the bar, we may suppose that the pressure is sufficient, or we may allow a circulation in the bar (Prendergast, loc. cit.). Now let us consider the transistion between a barred spiral of this kind (i.e., a very thin bar) and an ordinary spiral galaxy. To do this we allow the bar to get "fatter", which means that the forces other than the centrifugal force due to the rotation of the system as a whole are becoming more important. This can mean either that the pressure is increasing, or possibly that the velocity of circulation with respect to the bar is growing larger. For the same mass, we should expect that the rotation of the bar as a whole decreases, since there are now other ways of supporting the material against its own gravitation. The case we want to consider is the one in which the velocity of circulation increases, the velocity of rotation of the system as a whole decreases, and the pressure is not too important. We suggest that NGC 6951 and NGC 3504, to be seen in the Hubble Atlas, plate 46 (Sandage 1961), are cases of this type. We could not have high pressure in NGC 6951 without having a much more prominent nucleus. But this galaxy has a fat bar, and something must be supporting the material; this must be the centrifugal force due to circulation within the bar. For a very fat bar supported mainly by its internal circulation the velocity of rotation of the bar as a whole might be quite small. For NGC 3504, a steep velocity curve in the nucleus and a much smaller velocity toward the end of the bar was observed (Burbidge, Burbidge, and Prendergast 1960b). For this galaxy, the steep velocity curve in the nucleus might arise from the velocity of circulation, and the small velocity further out from the rotation as a whole. If this interpretation is correct, we should see features reminiscent of the spiral arms in ordinary spirals, whenever we encounter a barred spiral with a "fat bar" and small nucleus. Features which look as if they are such arms can be noted in these galaxies.

From its appearance NGC 613 is of the fat-bar type, seen closer to edge-on than NGC 6951. Since the nucleus is not big we conclude that the pressure is small, that there is a large velocity of circulation with respect to the bar, and that the velocity of rotation of the bar as a whole is probably small. Furthermore, we might be tempted to identify the outermost arms with escaping matter (i.e., matter escaping in the fashion computed for very thin-bar barred spirals). The "ordinary" arms can be seen at the boundaries of the bar, and perhaps some obscuring matter can be detected as well. Another way of expressing this is to say that a finite amplitude density wave goes around the galaxy at constant angular velocity, losing matter at the crest.

The observed run of velocities could be fitted into such a model, but at the present time there are so many possibilities that it is best to wait until the theoretical models are complete and to observe more barred spirals to see whether the type of velocity distribution found in NGC 613 and in NGC 5383 is very prevalent.

IV. THE MASS OF THE GALAXY

Because of the difficulty in interpreting the velocity field in the barred spiral NGC 613, we cannot make a mass estimate for the galaxy as a whole. However, the circulation of material in the center of the galaxy, with respect to the bar which is rotating as a whole, can be used to make a mass estimate for the nuclear region. If the material in the nucleus is treated as a uniform spheroid, rotating with constant angular velocity, the mass is given by

$$M_N = \frac{a\,V^2}{G\,\alpha} \; .$$

Here a is the semi-major axis of the nucleus, V is the circular velocity at the edge of the nuclear region, G is the gravitational constant, and α is a constant which is determined from the ratio of minor to major axis, c/a. For c/a = 0.5, α = 1.418. We consider first the Lick spectrum in position angle 105°.5, because the linear portion of the velocity curve is so well determined. From the observed radius of the nucleus, 7.5", and the observed velocity at the edge of the nucleus, 200 km/sec, and using the spatial orientation of the galaxy as adopted earlier to compute the projection factors, the nuclear mass comes out to be

$$M_N = 9 \times 10^9 \, M_\odot$$

The density is 11 $M_\odot/pc^3$. The same mass is found from the measures in position angle 115°, but the scatter in the velocities is larger in this case.

If we assume that at the point furthest from the center for which we have measures, the stream velocities are small and the observed velocities are Keplerian, we may compute a possible upper limit for the mass of the galaxy as a whole. Taking V_{max} = 240 km/sec at y = 85", for position angle 105°.5, and V_{max} = 200 km/sec at y = 80" for position angle 115°, and projecting these values into the plane of the galaxy for a position angle of the line of nodes equal to 115°, we find masses of 2.2×10^{11} and 1.3×10^{11} $M_\odot$, respectively. However, as can be seen from the discussion in Section III, such an estimate for the total mass is highly undertain.

We wish to thank Dr. Joan Crampin for carrying out some of the analysis of the spectra.

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TABLE 1

OBSERVATIONS OF NGC 613

Spectrum No.		Date	Position Angle	Exposure (minutes)	Slit Length	Dispersion (A/mm)
McDonald	B 679	Nov. 27, 1960	115°	120	290"	330
	B 681	Nov. 28, 1960	115°	30	290"	330
	B 683	Nov. 29, 1960	115°	120	290"	330
	B 684	Nov. 29, 1960	25°	30	290"	330
	B 688	Nov. 30, 1960	105°.5	120	290"	330
	B 690	Dec. 1, 1960	121°	120	290"	330
	B 709	Dec. 21, 1960	114°	125	290"	330
Lick	L 620	Oct. 24, 1963	105°.5	120	120"	195

TABLE 2

VELOCITIES IN NGC 613 (REDUCED TO LOCAL STANDARD OF REST)
AS A FUNCTION OF DISTANCE FROM CENTER

Distance From Center (Sec. of Arc)	Velocity (km/sec)
B 679	**P. A. 115°**
Hα:	
N.W. -80.8	+1642
-77.9	1721
-75.0	1784
-72.1	1840
-69.2	1827
- 9.9	1646
- 7.0	1623
- 4.1	1599
- 1.2	1545
+ 1.7	1491
+ 4.6	1407
+ 7.5	1383
S.E. +10.4	1359
[N II] 6583:	
N.W. - 7.1	1702
- 4.2	1641
- 1.3	1603
+ 1.6	1504
+ 4.5	1435
S.E. + 7.4	1411
B 681	**P. A. 115°**
Hα:	
N.W. - 5.2	1635
- 2.3	1559
+ 0.6	1505
+ 3.5	1497
+ 6.4	1466
S.E. + 9.3	1495
[N II] 6583:	
N.W. - 0.5	1502
+ 2.4	1464
+ 5.3	1403
+ 8.2	1387
S.E. +11.1	1386
B 683	**P. A. 115°**
Hα:	
N.W. -81.1	1669
-78.2	1687
-75.3	1644
-72.4	1624
-69.5	1649
-66.6	1643
-13.3	1688
-10.4	1748
- 7.5	1770
- 4.6	1686
- 1.8	1563
+ 1.1	1418
+ 4.0	1371
+ 6.9	1370
+ 9.8	1406
+12.7	1413
+95.0	1308
+97.9	1282
+100.8	1255
S.E. +103.6	1319
[N II] 6583:	
N.W. -10.1	1715
- 7.3	1729
- 4.4	1691
- 1.5	1576
+ 1.4	1469
+ 4.3	1423
B 683 (cont.)	**P. A. 115°**
[N II] 6583:	
+ 7.2	+1361
+10.1	1382
S.E. +15.2	1402
[S II] 6717:	
N.W. - 3.5	1736
- 0.6	1589
+ 2.3	1428
+ 5.2	1361
S.E. + 8.1	1353
B 684	**P. A. 25°**
Hα:	
N.E. - 5.2	1544
- 2.3	1513
+ 0.6	1527
S.W. + 3.5	1496
[N II] 6583:	
N.E. - 4.5	1533
- 1.6	1487
+ 1.3	1486
S.W. + 4.2	1500
B 688	**P. A. 105°.5**
Hα:	
N.W. -87.0	1800
-83.3	1782
-79.7	1778
-76.1	1767
-72.5	1740
-68.9	1743
-33.7	2013
-30.1	1998
-20.7	1863
-17.0	1841
-13.4	1825
-10.5	1772
- 7.6	1734
- 4.7	1695
- 1.8	1543
+ 1.1	1421
+ 4.0	1390
+ 6.9	1389
+ 9.8	1357
+12.6	1341
+15.5	1264
S.E. +18.4	1285
[N II] 6583:	
N.W. -13.1	1783
- 9.5	1655
- 5.9	1511
- 2.3	1465
+ 1.4	1433
+ 5.0	1372
+ 8.6	1355
S.E. +12.2	1384
B 690	**P. A. 121°**
Hα:	
N.W. -81.3	1676
-78.4	1656
-75.5	1697
-65.4	1766
-11.8	1692
- 9.1	1692
- 6.0	1707
B 690 (cont.)	**P. A. 121°**
Hα:	
- 3.1	+1660
- 0.2	1561
+ 2.6	1484
+ 5.5	1438
+ 8.4	1482
+83.1	1398
+86.0	1379
+88.9	1338
+91.8	1359
+94.7	1346
S.E. +97.6	1327
L 620	**P. A. 105°.5**
[N II] 6548:	
N.W. - 4.2	1594
- 2.6	1572
- 0.9	1537
+ 0.8	1505
+ 2.5	1466
+ 4.1	1408
S.E. + 5.8	1399
Hα:	
N.W. - 5.2	1659
- 3.5	1637
- 1.9	1593
- 0.2	1544
+ 1.5	1491
+ 3.2	1424
+ 4.9	1384
+ 6.5	1358
+ 8.2	1335
S.E. + 9.9	1313
[N II] 6583:	
N.W. - 4.4	1625
- 3.5	1620
- 1.9	1585
- 0.2	1523
+ 1.5	1492
+ 3.2	1435
+ 4.9	1382
+ 6.5	1346
S.E. + 8.2	1328
[S II] 6717:	
N.W. - 0.9	1501
+ 0.8	1480
+ 2.5	1415
+ 4.1	1354
S.E. + 5.8	1306

B 709 P. A. 114° (not through nucleus)	
Distance Along Spectrum (Sec. of Arc)	**Velocity (km/sec)**
Hα:	
N.W. 0.0	1508
+ 2.9	1476
+ 5.8	1437
+ 8.7	1436
+15.9	1425
+18.8	1393
+21.7	1406
+24.6	1389
+27.5	1395
S.E. +30.4	1377

FIGURE CAPTIONS

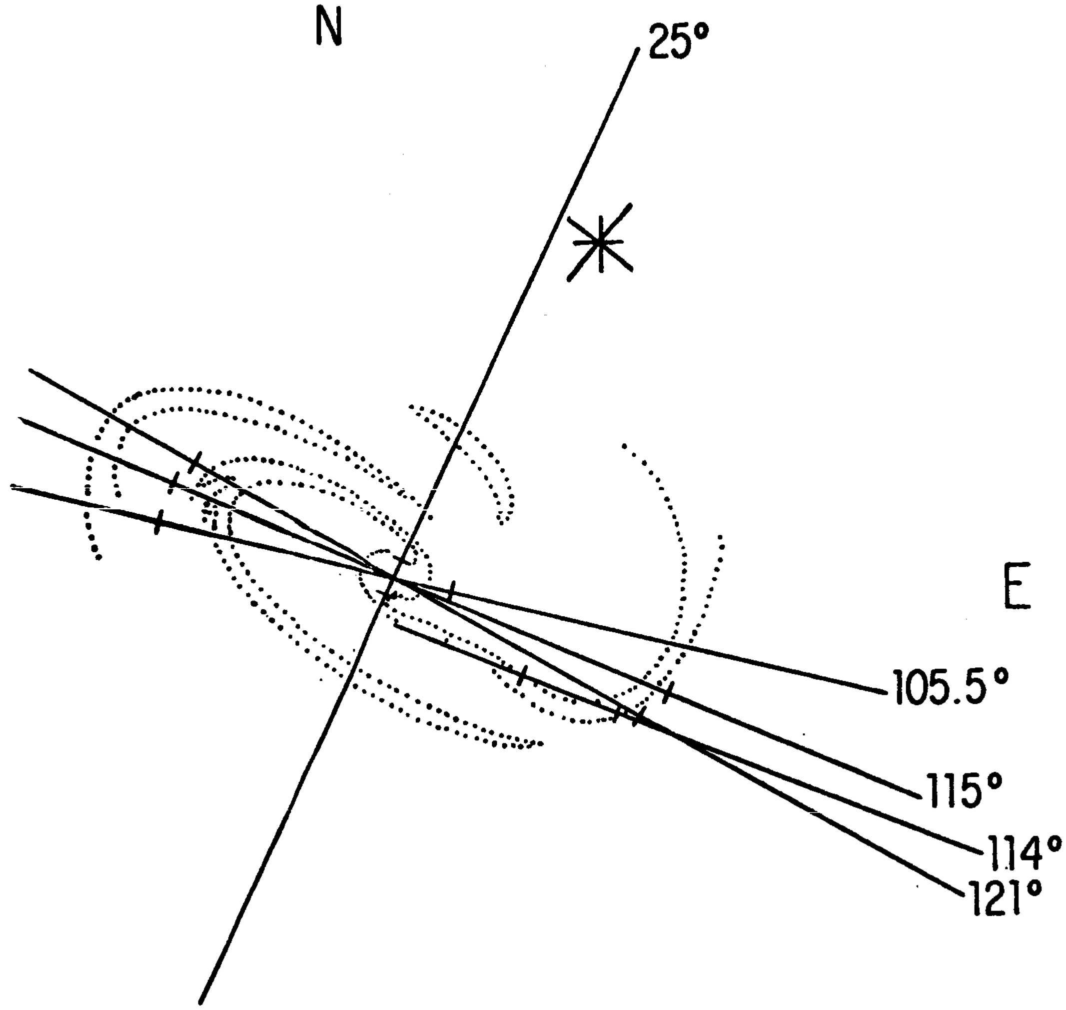
Fig. 1 - NGC 613, photographed at prime focus of McDonald 82-inch telescope on baked Eastman Kodak IIa-O plate. North is at top, west at left. Scale: 1 mm = 0.″0.

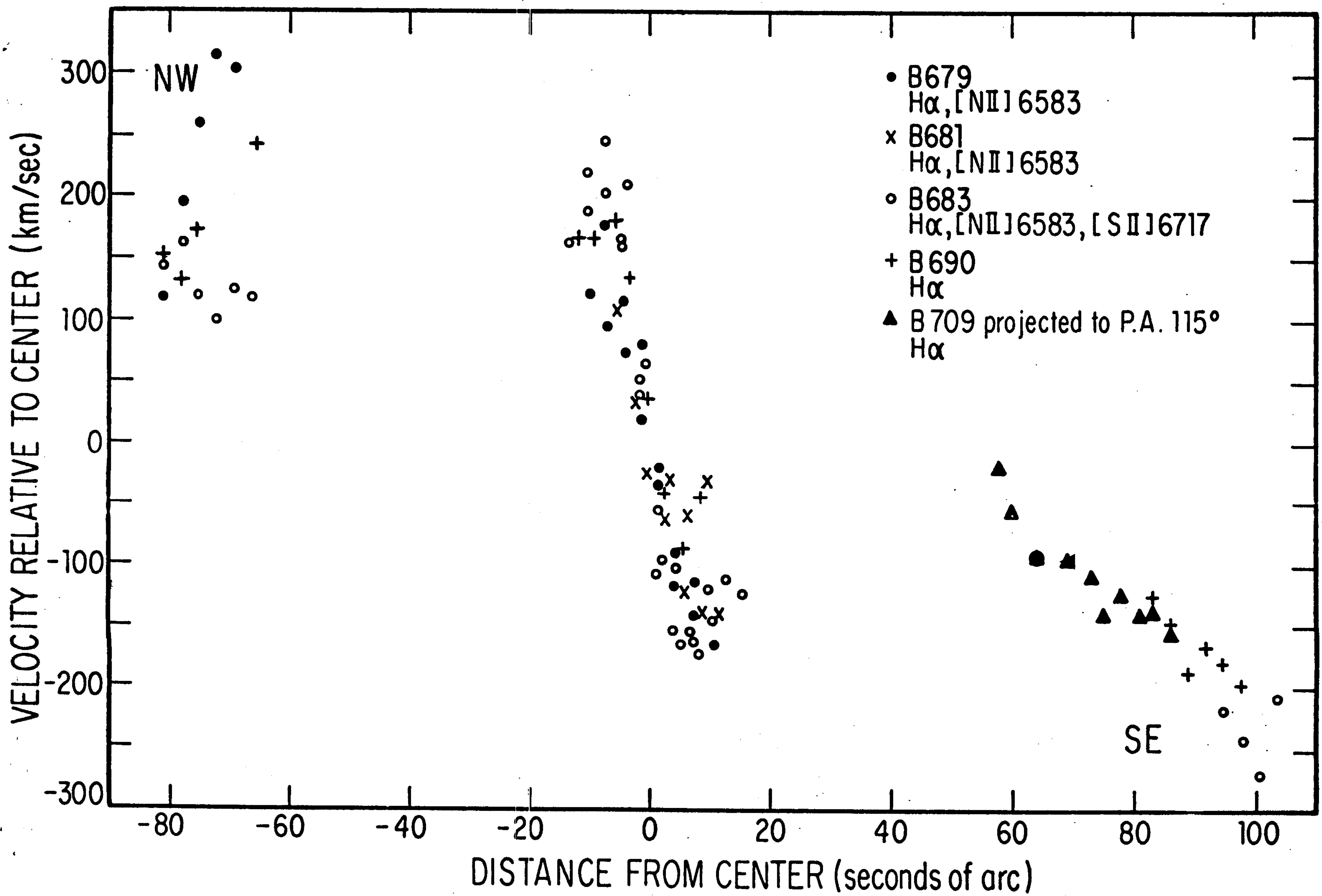
Fig. 2 - Red spectral region of NGC 613 with slit in P.A. 105°.5, showing inclined emission lines of [N II] λ6548, Hα, [N II] λ6583, [S II] λ6717, and [S II] λ6731. Plate taken with prime-focus spectrograph on Lick 120-inch telescope with thick Schmidt camera and grating giving dispersion 195 A/mm. Length of slit on sky was 2', and the north-west end of the slit appears at the top of the spectrum. Comparison spectrum is neon.

Fig. 3 - Sketch of NGC 613, showing slit orientations. Short bars indicate the limits within which velocities were measured.

Fig. 4 - Measured velocities, relative to the velocity of the center of the galaxy, from spectra B 688 and L 620 (P.A. 105°.5) plotted against distance from the center.

Fig. 5 - Measured velocities, relative to the velocity of the center of the galaxy, from spectra B 679, B 681, and B 683 (P.A. 115°), B 690 (P.A. 121°), and B 709 (P.A. 114° not through nucleus, reduced to P.A. 115°), plotted against distance from the center.


N
25°
E
105.5°
115°
114°
121°


VELOCITY RELATIVE TO CENTER (km/sec)
DISTANCE FROM CENTER (seconds of arc)
NW
SE
• B679 Hα,[NII]6583
× B681 Hα,[NII]6583
○ B683 Hα,[NII]6583,[SII]6717
+ B690 Hα
▲ B709 projected to P.A. 115° Hα
300
200
100
0
-100
-200
-300
-80
-60
-40
-20
0
20
40
60
80
100

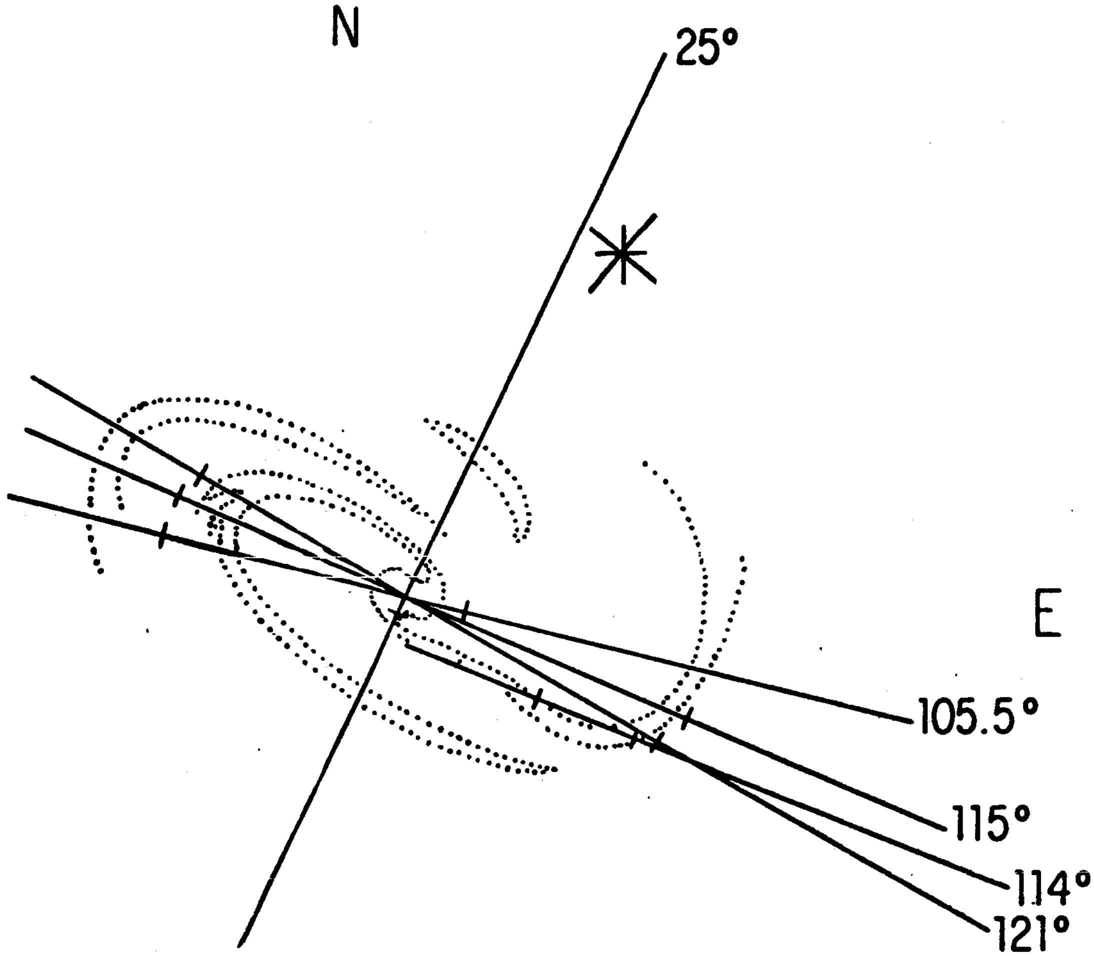
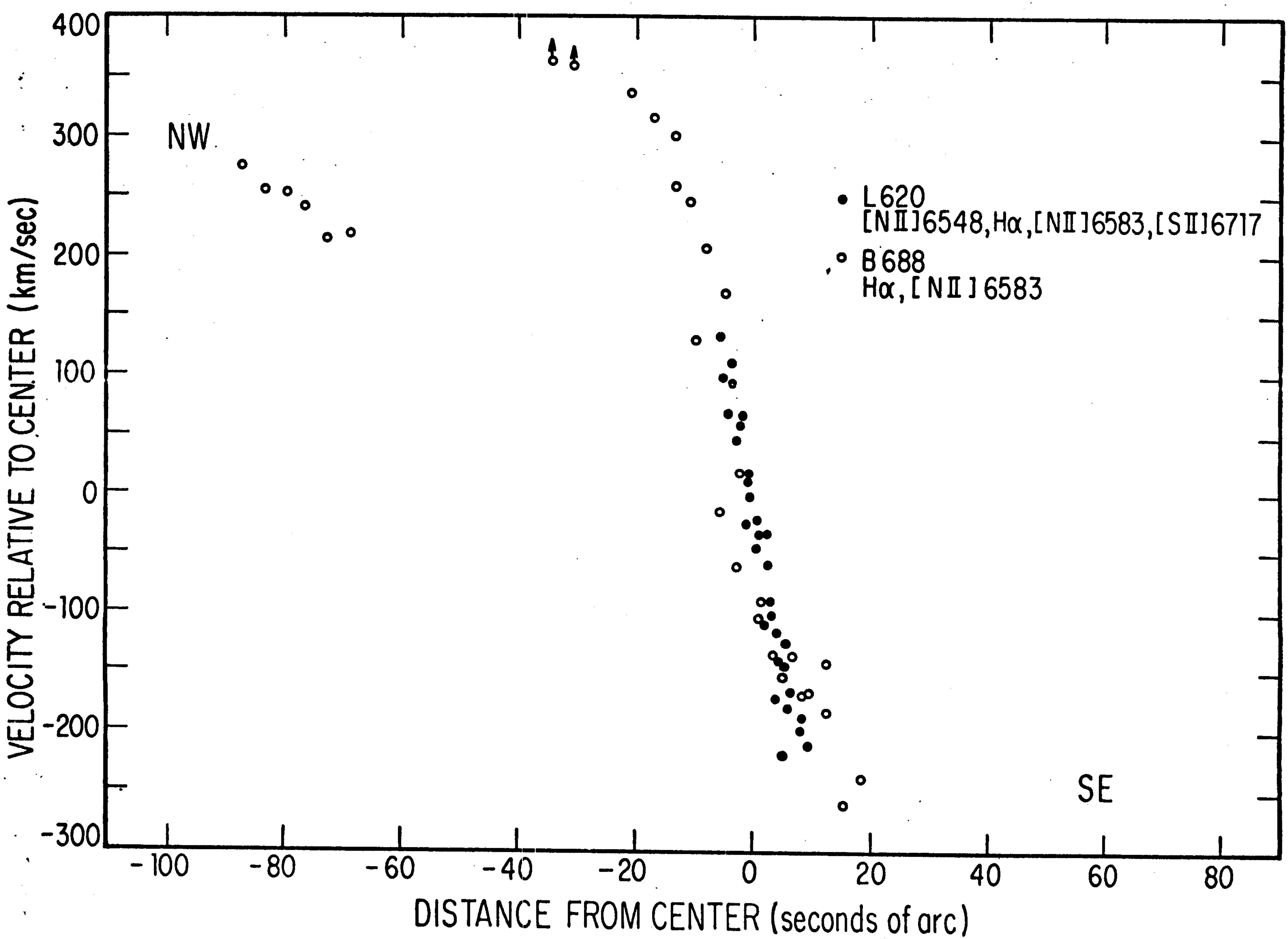
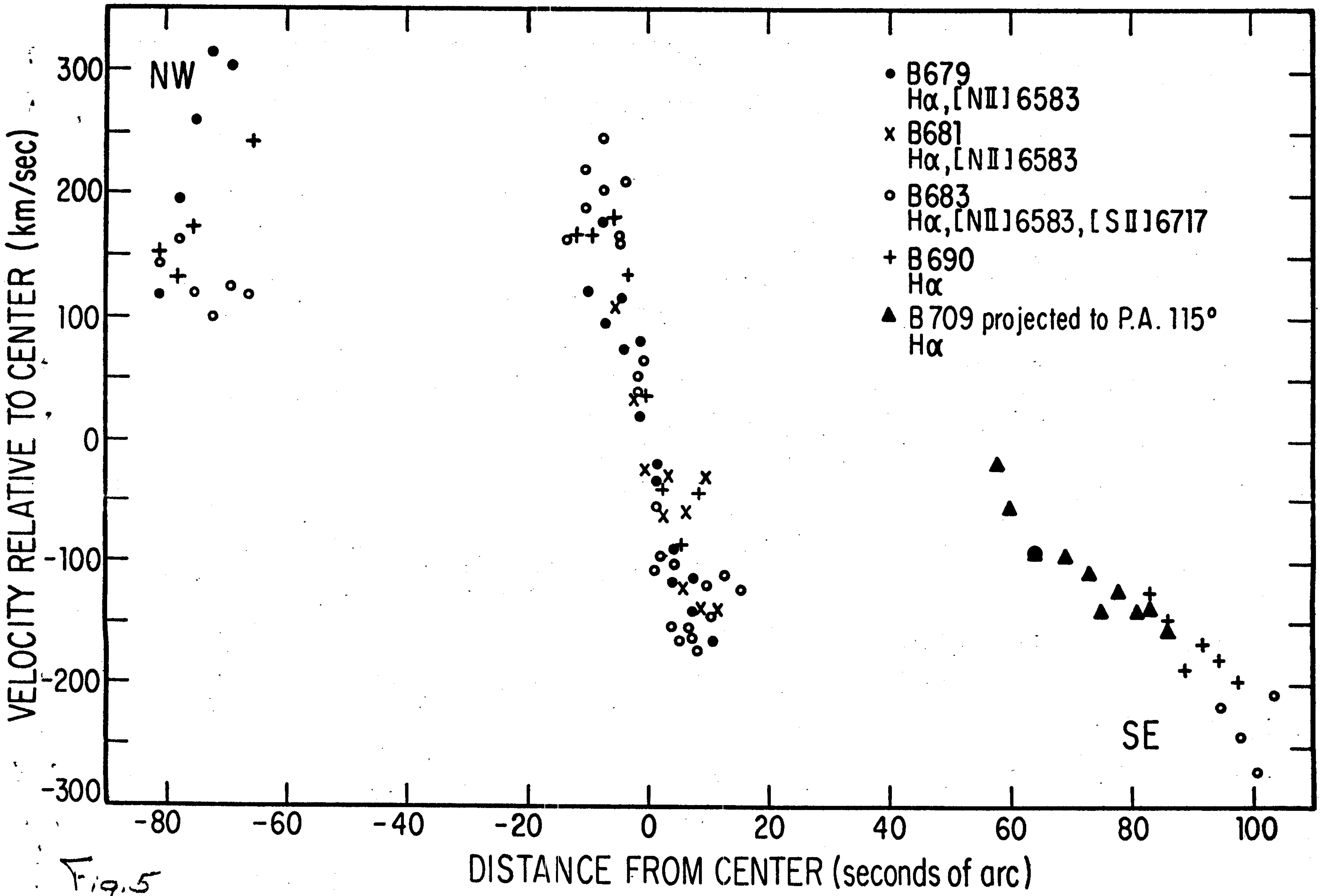


Fig. 3



VELOCITY RELATIVE TO CENTER (km/sec)
400
300
200
100
0
-100
-200
-300
NW
SE
L620
[NII]6548, Hα, [NII]6583, [SII]6717
B688
Hα, [NII]6583
-100
-80
-60
-40
-20
0
20
40
60
80
DISTANCE FROM CENTER (seconds of arc)



NW
SE
• B679 Hα, [NII] 6583
× B681 Hα, [NII] 6583
○ B683 Hα, [NII] 6583, [SII] 6717
+ B690 Hα
▲ B709 projected to P.A. 115° Hα
VELOCITY RELATIVE TO CENTER (km/sec)
DISTANCE FROM CENTER (seconds of arc)

Fig. 5